GBM/LAT LLE joint data analysis capability

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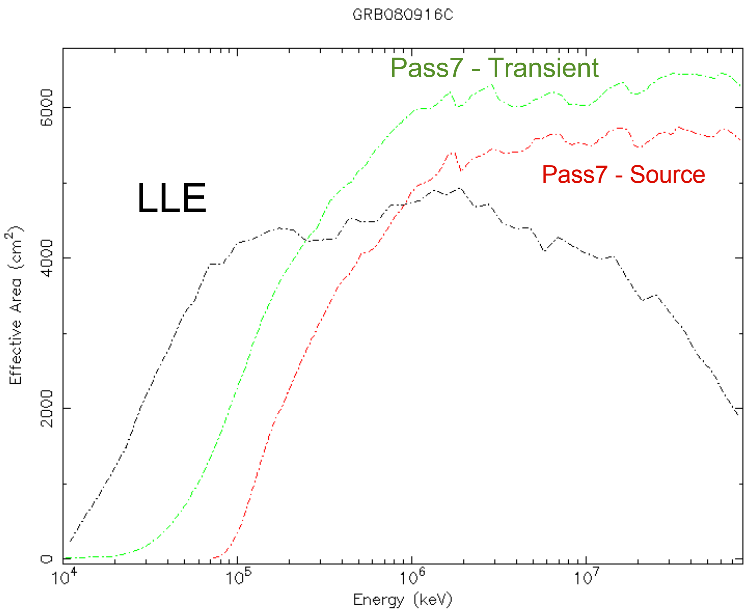
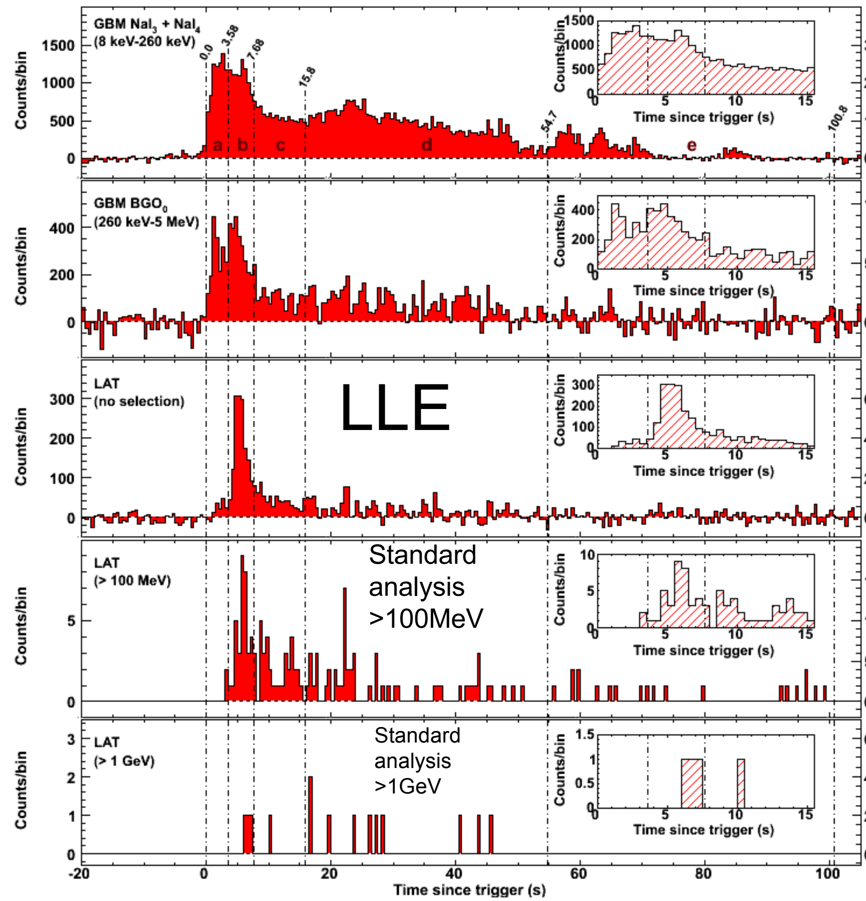
LAT Low Energy (LLE) analysis

- **How to think about the data**
  - **In our standard analysis (steady source, diffuse emission, flaring blazars,…) background rejection on “event by event” basis, using classification trees to reduce the particle contamination, classify the event, improve the quality of the signal (PSF, energy dispersion,…).**
  - **LLE Analysis: For GRBs, Solar Flares (rapid transients) we can also use the temporal profile to reduce the background. This information can be used to relax the “standard cuts” and open the effective area at low energy by an enormous amount.**



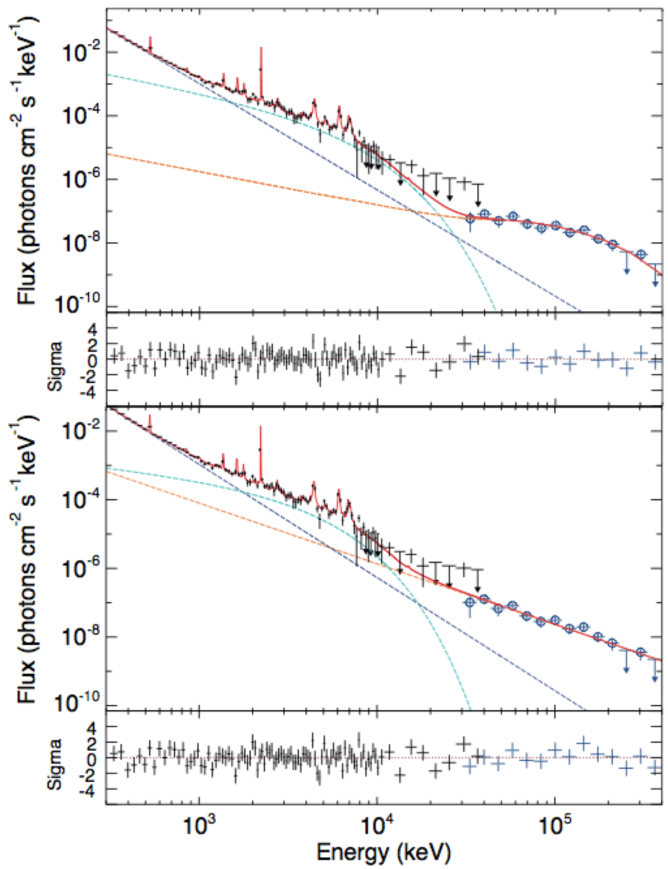


LLE analysis makes accessible a new energy range.

At high energy Standard analysis more efficient.

Opening new windows on transient sources

Solar Flares



During solar flares the high flux of hard X-rays causes pileup in the ACD. High probability to discard gamma-rays during the on-ground analysis due to ACD hits.
LLE is immune to this feature.

Delivery of LLE data products
Major -non scheduled- improvement!

Available Now

- New data products are delivered by the LAT team to the FSSC (<u>and to the public</u>)
- The new data products are delivered for <u>every GRBs and Solar Flare</u> detected in LLE data! (***to date: 23 GRBs and 5 Solar Flares***)
  - <u>LLE events:</u> un-binned event file, suitable for temporal studies (high resolution light curve >30 MeV)
  - <u>LLE spectrum files</u> (PHAII,PHAI and RSP): ready-to-use burst products in rmfit and XSPEC
  - <u>Quick look files</u> (png images)

<u>Usage Notes and Caveats</u>

a) The LLE data selection and response depend on the input localization of the GRB. Although the procedure to obtain LLE data and response is fully automatic, the update of the GBM trigger catalog is not, and this might introduce a latency in the delivery of the data products with the optimized location.

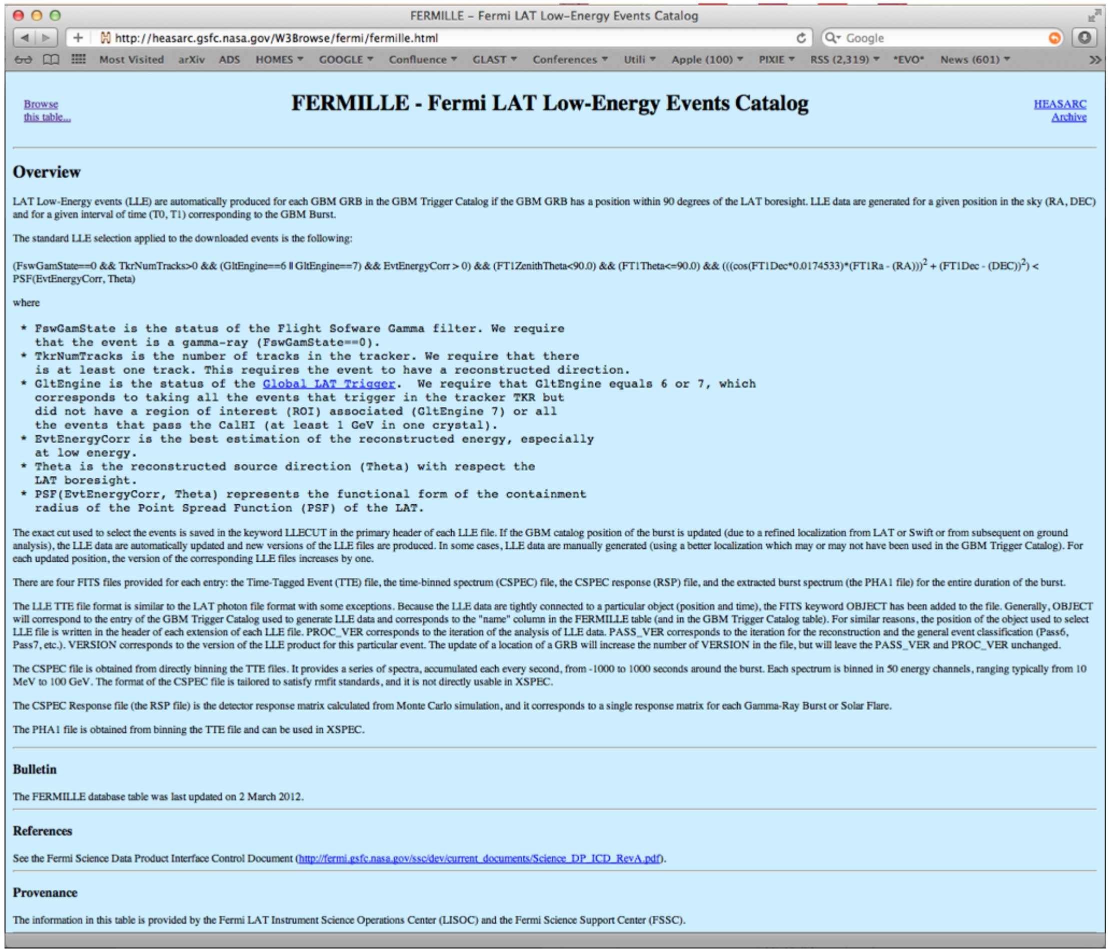
b) The Monte Carlo used to generate the response covers an energy range between 10 MeV and 100 GeV. At low energy (<100 MeV) the effect of the energy dispersion can be significant, and, with the current analysis, <u>we discourage any spectral analysis below 30 MeV.</u>

c) Above few hundred MeV (depending on the off axis angle of the event) the signal-to-noise ratio for standard data (TRANSIENT, SOURCE and cleaner event classes) is higher than for LLE data. <u>In case of bright events with emission above few hundred MeV we suggest using standard LAT event data at high energy and LLE data at low energy.</u>

d) The background in LLE is mainly driven by residual particle events and soft gamma-ray events in particular coming from the bright limb of the Earth. During Autonomous Repoint Requests (ARR), a significant fraction of the Earth limb enters the LAT field of view and an increase of the event rate is clearly visible in LLE data. <u>We urge users to exercise care in the treatment of the Earth limb.</u>

e) Data and response are, by construction, related to each other. In case of updates, <u>we recommend updating both the response and the data, making sure that the version number is the same.</u>

Serving the community: The LLE data portal @ FSSC


FERMILLE – Fermi LAT Low-Energy Events Catalog

http://heasarc.gsfc.nasa.gov/W3Browse/fermi/fermille.html

Browse this table...

FERMILLE - Fermi LAT Low-Energy Events Catalog

HEASARC Archive

Overview

LAT Low-Energy events (LLE) are automatically produced for each GBM GRB in the GBM Trigger Catalog if the GBM GRB has a position within 90 degrees of the LAT boresight. LLE data are generated for a given position in the sky (RA, DEC) and for a given interval of time (T0, T1) corresponding to the GBM Burst.

The standard LLE selection applied to the downloaded events is the following:

(FswGamState==0 && TkrNumTracks>0 && (GltEngine==6 || GltEngine==7) && EvtEnergyCorr > 0) && (FT1ZenithTheta<90.0) && (FT1Theta<=90.0) && (((cos(FT1Dec*0.0174533)*(FT1Ra - (RA)))^2 + (FT1Dec - (DEC))^2) < PSF(EvtEnergyCorr, Theta)

where

```
 * FswGamState is the status of the Flight Sofware Gamma filter. We require
   that the event is a gamma-ray (FswGamState==0).
 * TkrNumTracks is the number of tracks in the tracker. We require that there
   is at least one track. This requires the event to have a reconstructed direction.
 * GltEngine is the status of the Global LAT Trigger.  We require that GltEngine equals 6 or 7, which
   corresponds to taking all the events that trigger in the tracker TKR but
   did not have a region of interest (ROI) associated (GltEngine 7) or all
   the events that pass the CalHI (at least 1 GeV in one crystal).
 * EvtEnergyCorr is the best estimation of the reconstructed energy, especially
   at low energy.
 * Theta is the reconstructed source direction (Theta) with respect the
   LAT boresight.
 * PSF(EvtEnergyCorr, Theta) represents the functional form of the containment
   radius of the Point Spread Function (PSF) of the LAT.
```

The exact cut used to select the events is saved in the keyword LLECUT in the primary header of each LLE file. If the GBM catalog position of the burst is updated (due to a refined localization from LAT or Swift or from subsequent on ground analysis), the LLE data are automatically updated and new versions of the LLE files are produced. In some cases, LLE data are manually generated (using a better localization which may or may not have been used in the GBM Trigger Catalog). For each updated position, the version of the corresponding LLE files increases by one.

There are four FITS files provided for each entry: the Time-Tagged Event (TTE) file, the time-binned spectrum (CSPEC) file, the CSPEC response (RSP) file, and the extracted burst spectrum (the PHA1 file) for the entire duration of the burst.

The LLE TTE file format is similar to the LAT photon file format with some exceptions. Because the LLE data are tightly connected to a particular object (position and time), the FITS keyword OBJECT has been added to the file. Generally, OBJECT will correspond to the entry of the GBM Trigger Catalog used to generate LLE data and corresponds to the "name" column in the FERMILLE table (and in the GBM Trigger Catalog table). For similar reasons, the position of the object used to select LLE file is written in the header of each extension of each LLE file. PROC_VER corresponds to the iteration of the analysis of LLE data. PASS_VER corresponds to the iteration for the reconstruction and the general event classification (Pass6, Pass7, etc.). VERSION corresponds to the version of the LLE product for this particular event. The update of a location of a GRB will increase the number of VERSION in the file, but will leave the PASS_VER and PROC_VER unchanged.

The CSPEC file is obtained from directly binning the TTE files. It provides a series of spectra, accumulated each every second, from -1000 to 1000 seconds around the burst. Each spectrum is binned in 50 energy channels, ranging typically from 10 MeV to 100 GeV. The format of the CSPEC file is tailored to satisfy rmfit standards, and it is not directly usable in XSPEC.

The CSPEC Response file (the RSP file) is the detector response matrix calculated from Monte Carlo simulation, and it corresponds to a single response matrix for each Gamma-Ray Burst or Solar Flare.

The PHA1 file is obtained from binning the TTE file and can be used in XSPEC.

Bulletin

The FERMILLE database table was last updated on 2 March 2012.

References

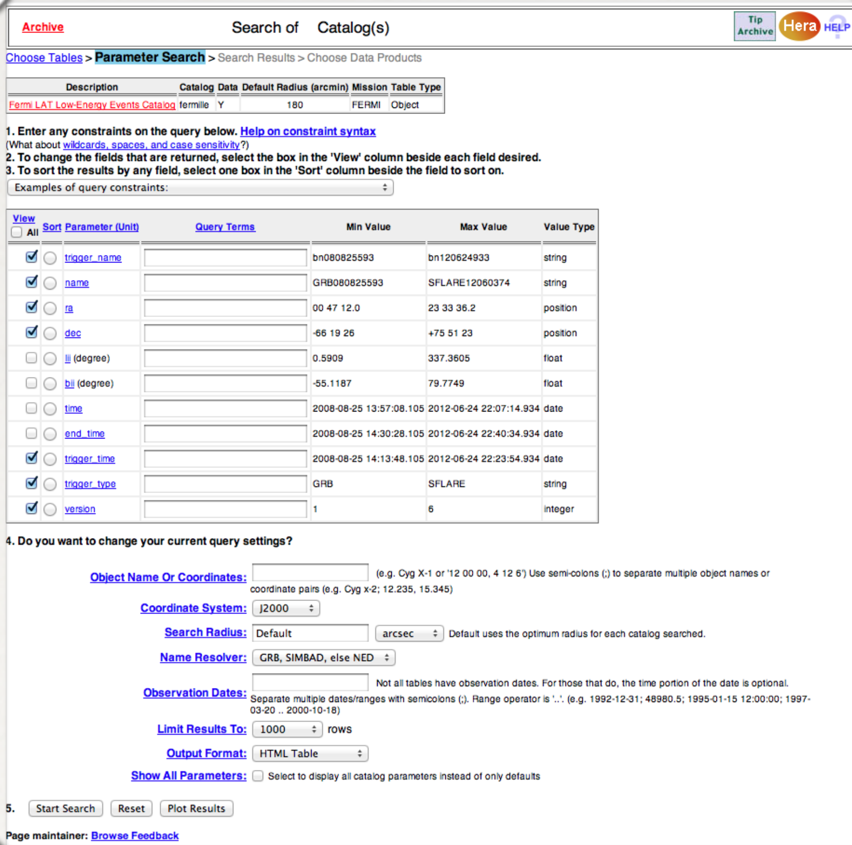
See the Fermi Science Data Product Interface Control Document (http://fermi.gsfc.nasa.gov/ssc/dev/current_documents/Science_DP_ICD_RevA.pdf).

Provenance

The information in this table is provided by the Fermi LAT Instrument Science Operations Center (LISOC) and the Fermi Science Support Center (FSSC).

- **All the LLE data products as well as usage notes, caveats, data description will be uploaded to the FSSC *Browse* web interface**
- **Expect a latency of LLE data ~ 48 hours (+ updates)**

LLE catalog of GRBs and Solar Flares



Archive | Search of Catalog(s) | Tip Archive | Hera | HELP

Choose Tables > **Parameter Search** > Search Results > Choose Data Products

Description	Catalog	Data	Default Radius (arcmin)	Mission	Table Type
Fermi LAT Low-Energy Events Catalog	fermlle	Y	180	FERMI	Object

1. Enter any constraints on the query below. Help on constraint syntax
(What about wildcards, spaces, and case sensitivity?)
2. To change the fields that are returned, select the box in the 'View' column beside each field desired.
3. To sort the results by any field, select one box in the 'Sort' column beside the field to sort on.

Examples of query constraints:

View All	Sort	Parameter (Unit)	Query Terms	Min Value	Max Value	Value Type
☑	○	trigger_name		bn080825593	bn120624933	string
☑	○	name		GRB080825593	SFLARE12060374	string
☑	○	ra		00 47 12.0	23 33 36.2	position
☑	○	dec		-66 19 26	+75 51 23	position
☐	○	lii (degree)		0.5909	337.3605	float
☐	○	bii (degree)		-55.1187	79.7749	float
☐	○	time		2008-08-25 13:57:08.105	2012-06-24 22:07:14.934	date
☐	○	end_time		2008-08-25 14:30:28.105	2012-06-24 22:40:34.934	date
☑	○	trigger_time		2008-08-25 14:13:48.105	2012-06-24 22:23:54.934	date
☑	○	trigger_type		GRB	SFLARE	string
☑	○	version		1	6	integer

4. Do you want to change your current query settings?

Object Name Or Coordinates: (e.g. Cyg X-1 or '12 00 00, 4 12 6') Use semi-colons (;) to separate multiple object names or coordinate pairs (e.g. Cyg x-2; 12.235, 15.345)

Coordinate System: J2000

Search Radius: Default arcsec Default uses the optimum radius for each catalog searched.

Name Resolver: GRB, SIMBAD, else NED

Observation Dates: Not all tables have observation dates. For those that do, the time portion of the date is optional. Separate multiple dates/ranges with semicolons (;). Range operator is '..'. (e.g. 1992-12-31; 48980.5; 1995-01-15 12:00:00; 1997-03-20 .. 2000-10-18)

Limit Results To: 1000 rows

Output Format: HTML Table

Show All Parameters: Select to display all catalog parameters instead of only defaults

5. Start Search | Reset | Plot Results

Page maintainer: Browse Feedback

Archive | Query Results | Tip Archive | Hera | HELP

Choose Tables > Parameter Search > **Search Results** > Choose Data Products

Search was based on:
Coord. System: Equatorial, equinox 2000
Maximum Rows: 1000
Reissue Query | Save Query To File

Redisplay as Tabbed Display | Printer-Friendly Version | Save All Objects To File | Reset

Browse Tip: Do you know how to cross-correlate two tables? Learn more on this topic or See all tips

Table Name and Row Count

fermlle:Fermi LAT Low-Energy Events Catalog 28

Table Legend:
Display all parameters for a row
Sort by a column in order: 1,2,3 Sort by column in reverse order: 3,2,1 Current table sort
Services links: O: Digitized Sky Survey image, R: ROSAT All-Sky Survey image, N: NED objects near coordinates, S: SIMBAD objects near coordinates, D: get list of data products, H: analyze data products using Hera, B: ADS bibliography holdings, F: FOV plot for observation
Scroll down below tables to select Data Products and Further Actions.

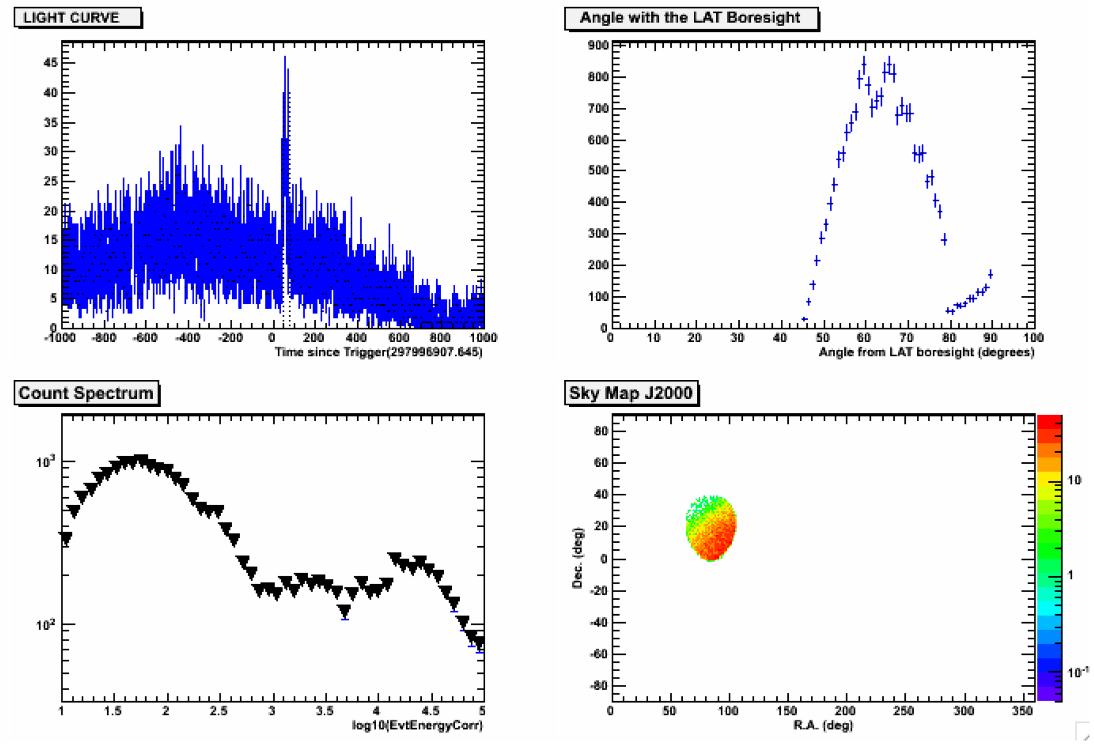
Fermi LAT Low-Energy Events Catalog (fermlle) Bulletin

Select All	Services	trigger_name	name	ra	dec	lii [degree]	bii [degree]	time	end_time	trigger_time	trigger_type	version
	O R N S D H	bn090926181	GRB090926181	23 33 36.2	-66 19 26	314.6944	-48.9886	2009-09-26 04:03:46.987	2009-09-26 04:37:06.987	2009-09-26 04:20:26.987	GRB	1
	O R N S D H	bn100225115	GRB100225115	20 41 12.0	-59 24 00	337.3605	-36.9601	2010-02-25 02:28:51.147	2010-02-25 03:02:11.147	2010-02-25 02:45:31.147	GRB	1
	O R N S D H	bn091031500	GRB091031500	04 42 19.2	-59 04 48	268.6959	-39.4503	2009-10-31 11:43:48.846	2009-10-31 12:17:08.846	2009-10-31 12:00:28.846	GRB	1
	O R N S D H	bn080916009	GRB080916009	07 59 12.0	-56 36 00	270.1009	-13.7641	2008-09-15 23:56:05.613	2008-09-16 00:29:25.613	2008-09-16 00:12:45.613	GRB	6
	O R N S D H	bn090328401	GRB090328401	06 03 36.0	-42 00 00	248.7817	-26.2422	2009-03-28 09:20:06.511	2009-03-28 09:53:26.511	2009-03-28 09:36:46.511	GRB	1
	O R N S D H	bn110721200	GRB110721200	22 12 48.0	-38 30 00	3.7184	-55.0915	2011-07-21 04:31:03.761	2011-07-21 05:04:23.761	2011-07-21 04:47:43.761	GRB	2
	O R N S D H	bn110731465	GRB110731465	18 42 01.0	-28 32 14	6.2233	-10.7021	2011-07-31 10:52:49.954	2011-07-31 11:26:09.954	2011-07-31 11:09:29.954	GRB	1
	O R N S D H	bn090510016	GRB090510016	22 14 24.0	-26 36 00	24.6062	-55.1187	2009-05-10 00:06:19.971	2009-05-10 00:39:39.971	2009-05-10 00:22:59.971	GRB	1
	O R N S D H	bn100826957	GRB100826957	18 56 00.0	-23 11 24	12.5135	-11.2939	2010-08-26 22:41:42.898	2010-08-26 23:15:02.898	2010-08-26 22:58:22.898	GRB	1
	O R N S D H	bn090217206	GRB090217206	13 39 36.0	-08 24 00	322.7965	52.6043	2009-02-17 04:40:02.558	2009-02-17 05:13:22.558	2009-02-17 04:56:42.558	GRB	1
	O R N S D H	bn080825593	GRB080825593	15 36 00.0	-04 42 00	0.5909	39.0968	2008-08-25 13:57:08.105	2008-08-25 14:30:28.105	2008-08-25 14:13:48.105	GRB	3
	O R N S D H	bn110924399	SFLARE11092439	12 03 05.0	-00 20 03	278.0272	60.1784	2011-09-24 09:17:58.651	2011-09-24 09:51:18.651	2011-09-24 09:34:38.651	SFLARE	1
	O R N S D H	bn101123952	GRB101123952	09 00 38.4	+01 54 36	227.1381	29.3739	2010-11-23 22:34:54.974	2010-11-23 23:08:14.974	2010-11-23 22:51:34.974	GRB	1
	O R N S D H	bn110906929	SFLARE11090692	11 00 21.4	+06 21 55	246.0705	56.4267	2011-09-06 22:00:37.880	2011-09-06 22:33:57.880	2011-09-06 22:17:17.880	SFLARE	1
	O R N S D H	bn120624933	GRB120624933	11 23 45.6	+08 55 48	250.1146	62.4272	2012-06-24 22:07:14.934	2012-06-24 22:40:34.934	2012-06-24 22:23:54.934	GRB	4
	O R N S D H	bn100116897	GRB100116897	20 20 04.8	+14 27 00	56.3613	-12.1987	2010-01-16 21:14:20.242	2010-01-16 21:47:40.242	2010-01-16 21:31:00.242	GRB	1
	O R N S D H	bn110809334	SFLARE11080933	09 14 50.4	+15 57 51	213.8125	38.7962	2011-08-09 07:44:21.196	2011-08-09 08:17:41.196	2011-08-09 08:01:01.196	SFLARE	1
	O R N S D H	bn090323002	GRB090323002	12 42 48.0	+17 06 00	291.2262	79.7749	2009-03-22 23:46:02.627	2009-03-23 00:19:22.627	2009-03-23 00:02:42.627	GRB	1
	O R N S D H	bn081024891	GRB081024891	21 31 36.0	+21 12 00	72.7622	-21.6485	2008-10-24 21:06:00.864	2008-10-24 21:39:20.864	2008-10-24 21:22:40.864	GRB	2
	O R N S D H	bn120603745	SFLARE12060374	04 47 52.8	+22 24 11	177.9282	-14.3967	2012-06-03 17:35:53.902	2012-06-03 18:09:13.902	2012-06-03 17:52:33.902	SFLARE	2

LLE data product (bn100612038)

- gll_lle_bn100612038_v04.fits : LLE events, FT1 file format, basically
- gll_cspec_bn100612038_v04.pha (cspec file format, ready to be used in rmfit)
- gll_cspec_bn100612038_v04.rsp (response file, rmfit and XSPEC)

- gll_pha_bn100612038_v04.fit (PHAI file)
- gll_pt_bn100612038_v04.fit (FT2 – 1 second)
- gll_selected_bn100612038_v04.fit (selected events for the selected time interval)



In this tutorial

- Learn how to analyze LLE data
  - Compute the background;
  - Extract PHA1 spectrum file;
  - Use XSPEC to analyze LLE and GBM data

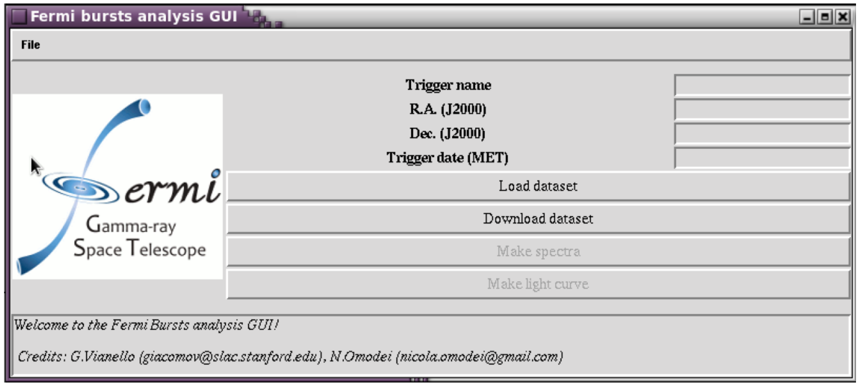
- LLE data (publicly available):
  - cspec file
  - Rsp file
- GBM data (publicly available, for some flares you will need to compute the response using HERA, or use the pre-computed ones:
  - http://hesperia.gsfc.nasa.gov/fermi/gbm/rsp/
  - Cspec file
  - Rspfile

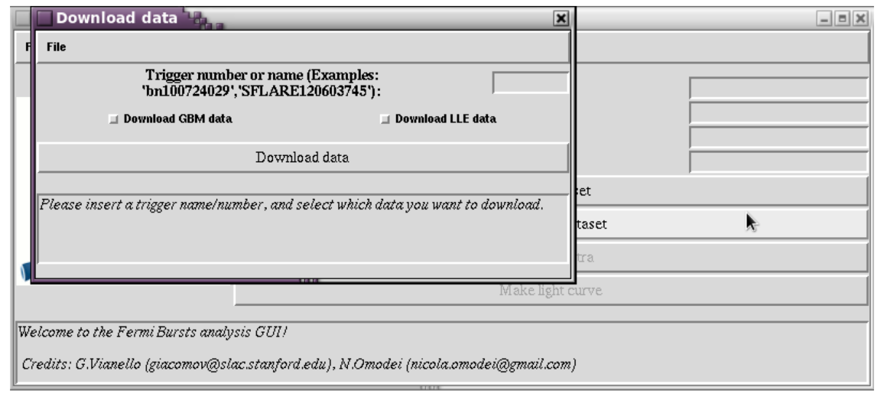
LLE analysis GUI

- We have written a simple tool to help in the analysis of LLE data
  - Wrapper around Fermi Science Tools
  - Graphical User Interface
- Why reinventing the wheel?
  - Tool optimized for LLE data (but can work with GBM CSPEC files)
    - Low counts: use poissonian likelihood
    - Download LLE the data from the FSSC
  - Produces (OGIP) PHA2 files that can be converted in PHA1 and used in several fitting programs (OSPEX,XSPEC,rmfit)

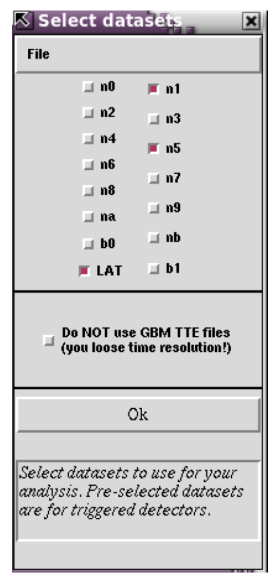
LLE Analysis GUI

- **In SolarTutorial/lleBackground**
- **./lleGUI.py**



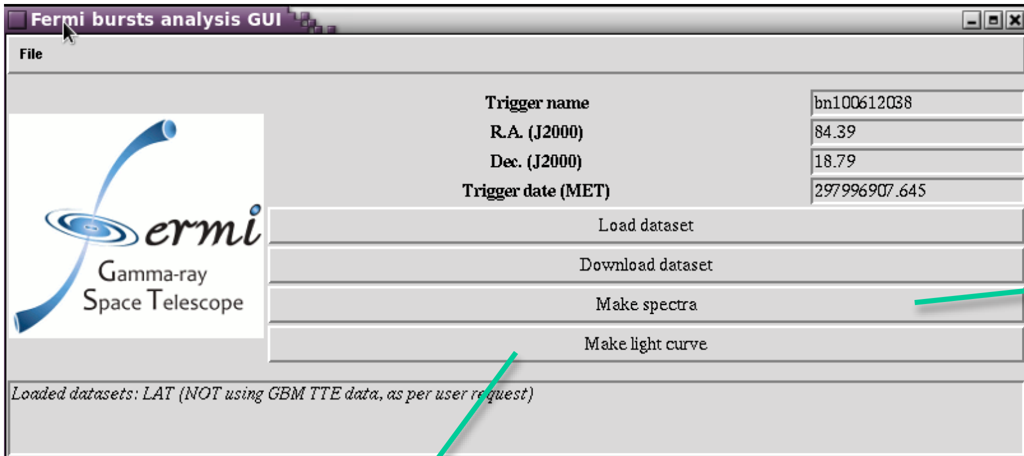


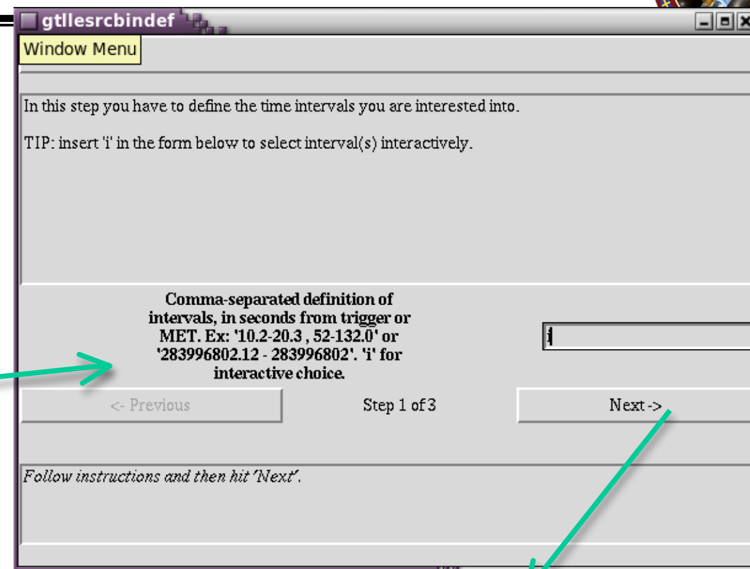
- **Select both GBM and LLE data**
- **Select only the RSP (no CTIME nor TTE)**

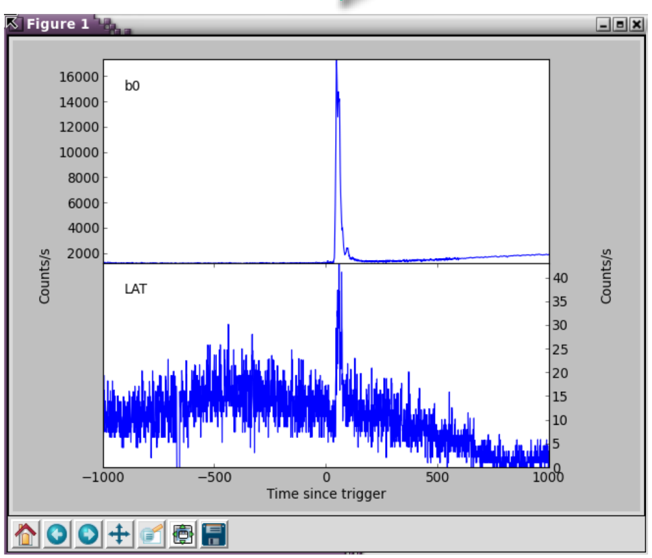


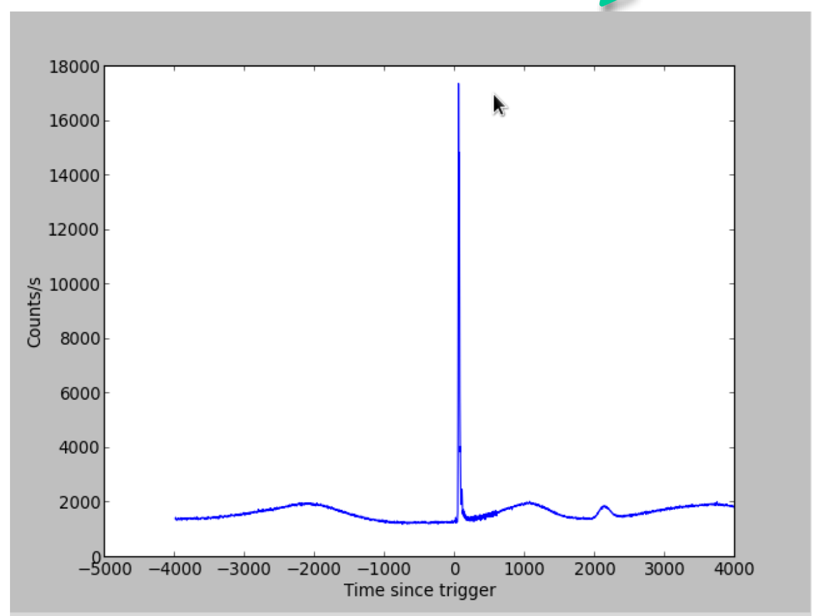
Select only b0 and LAT

LLE Analysis GUI

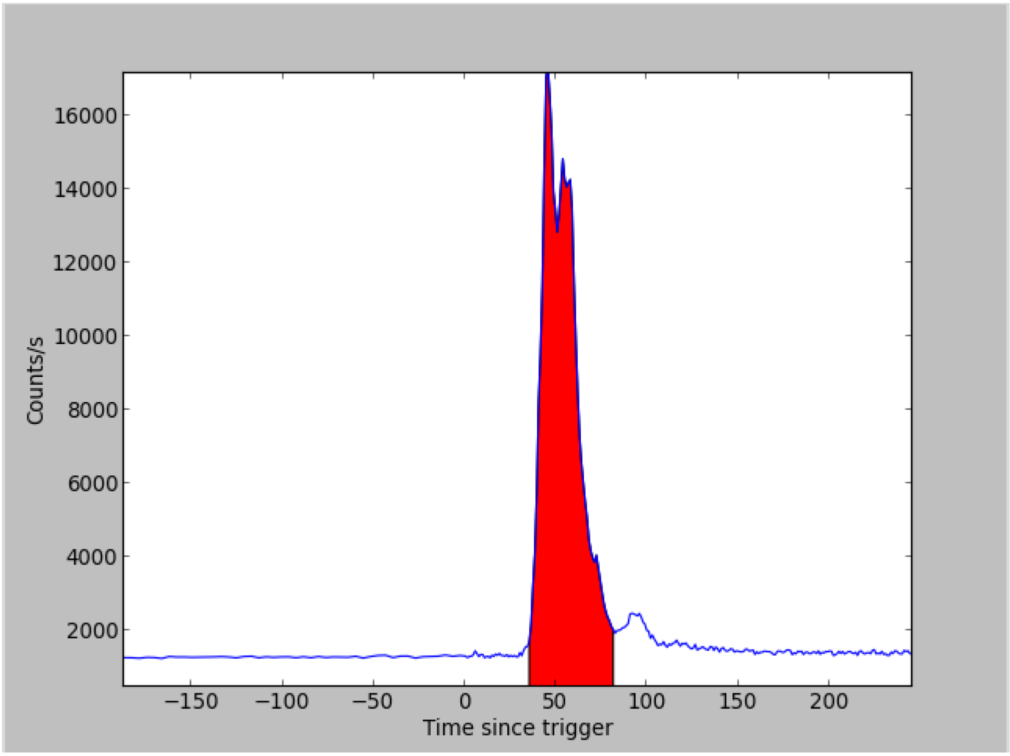




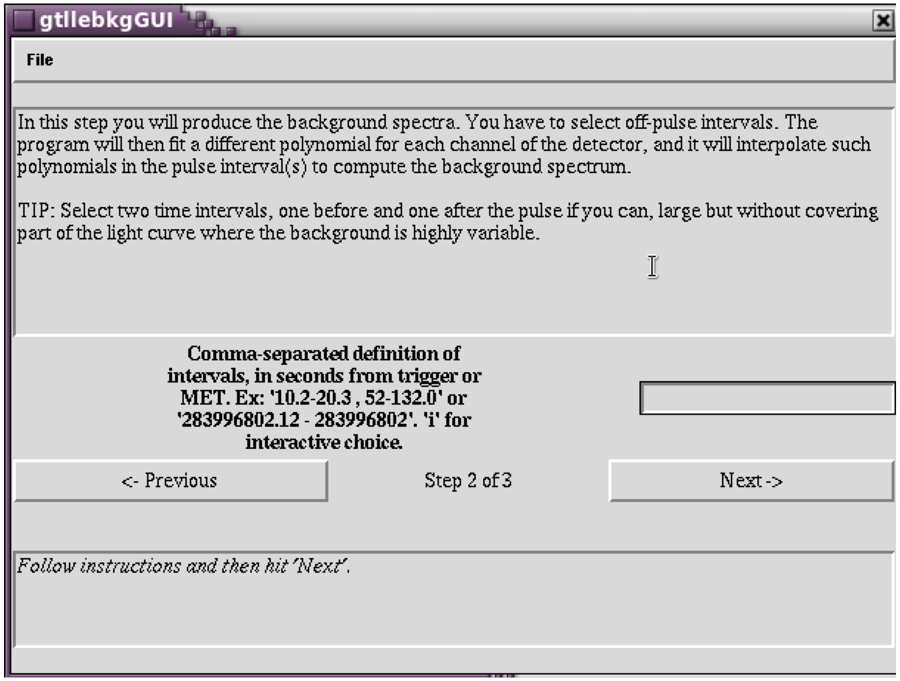


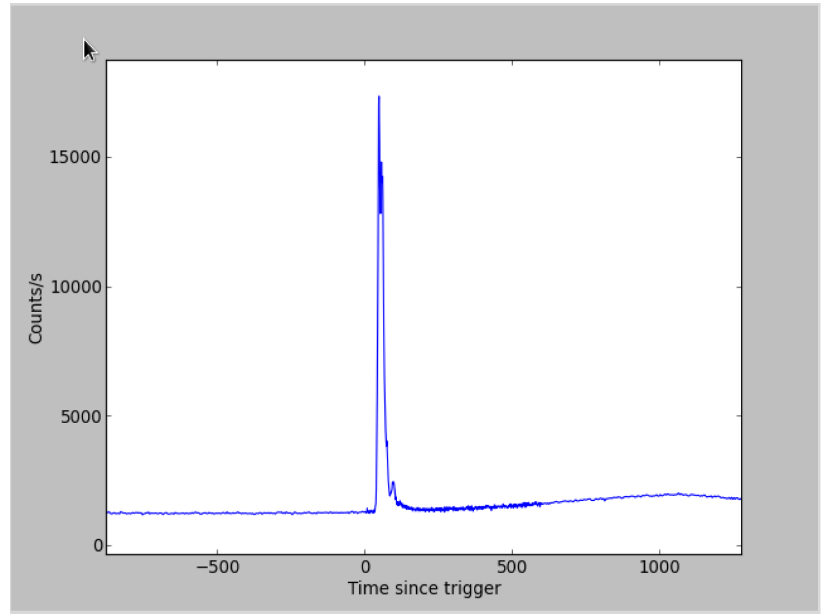


Select the signal

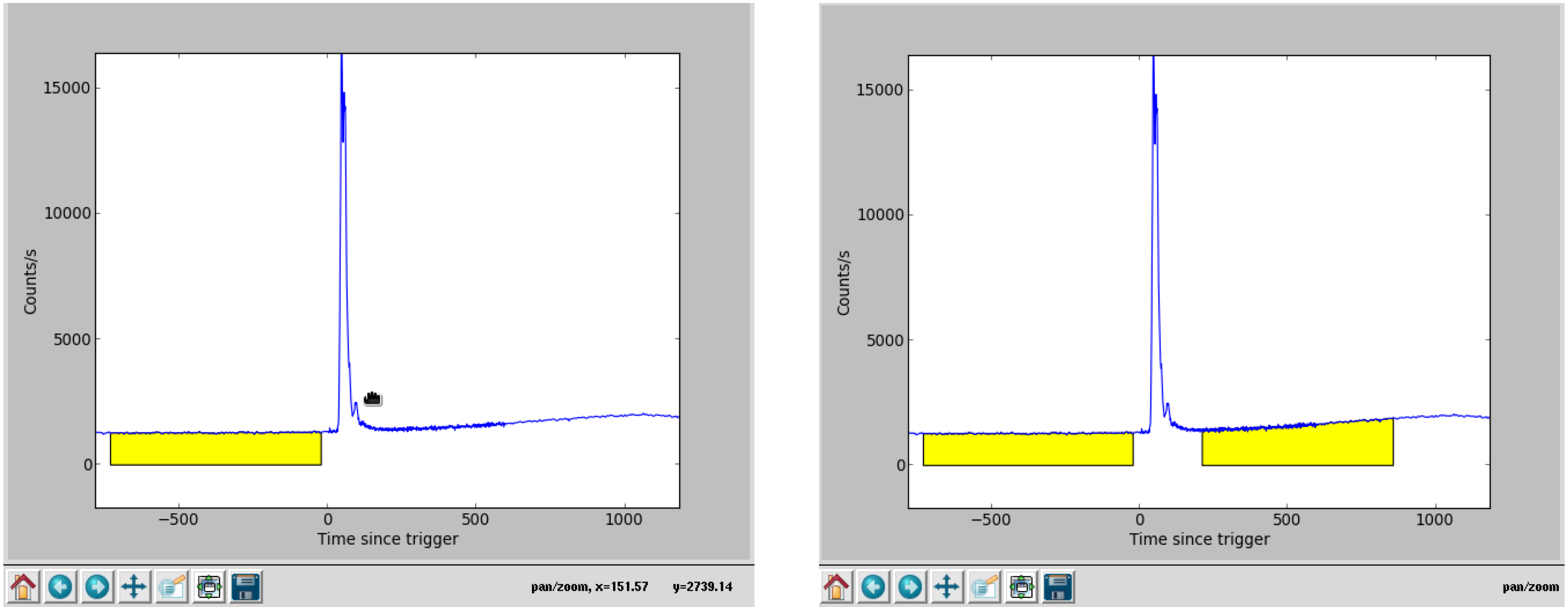


Press **p**, to zoom (right click, 2 finger click on MAC)
Hold **x**, click on the start, then click on the end
Hold **q** and click.


gtllebkgGUI
File
In this step you will produce the background spectra. You have to select off-pulse intervals. The program will then fit a different polynomial for each channel of the detector, and it will interpolate such polynomials in the pulse interval(s) to compute the background spectrum.
TIP: Select two time intervals, one before and one after the pulse if you can, large but without covering part of the light curve where the background is highly variable.
Comma-separated definition of intervals, in seconds from trigger or MET. Ex: '10.2-20.3 , 52-132.0' or '283996802.12 - 283996802'. 'i' for interactive choice.
<- Previous
Step 2 of 3
Next ->
Follow instructions and then hit 'Next'.

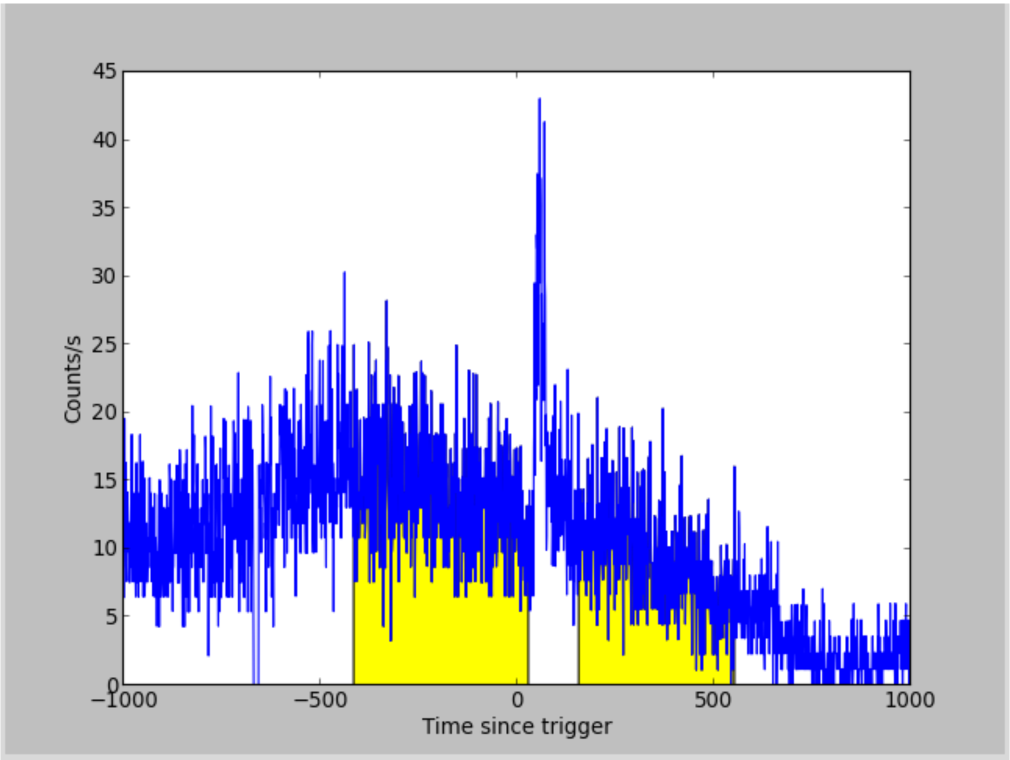

15000
10000
5000
0
Counts/s
−500
0
500
1000
Time since trigger

Select the pre-flare background



Hold **z**, click on the *start*, then click on the *end* of the interval you want to select

Select the post-flare background



Hold **z**, click on the *start*, then click on the *end* of the interval you want to select

Results:

- A series of output files have been produced:
  - LAT_bkgintervals.out
  - LAT_srcintervals.out
  - LAT_bkgspectra.out   THIS IS A PHAII file
  - LAT_srcspectra.out THIS IS A PHAII file
- Produces a xspec file to load the data.

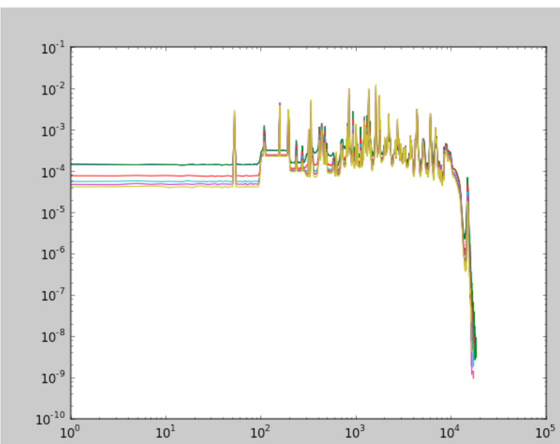
- If you want to use PHA I instead:
  - cmppha -- Converts a TYPE II to a TYPE I OGIP pha file

Fitting with XSPEC

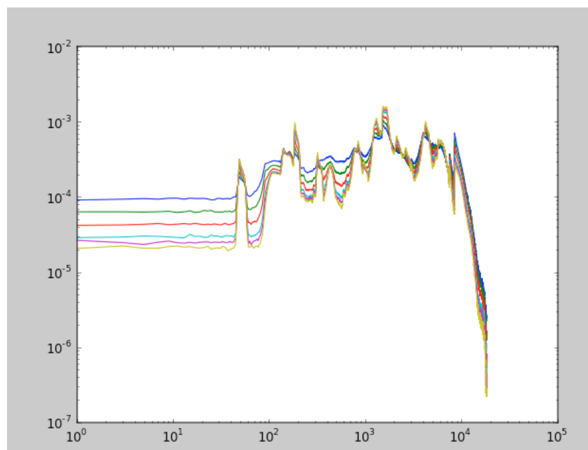
Solar flare analysis requires the use of spectrum templates (nuclear lines, pion model)

We have generated tabular models (*atable*) for Narrow Nuclear Lines and Broad Nuclear Lines, as well as pion decay models.

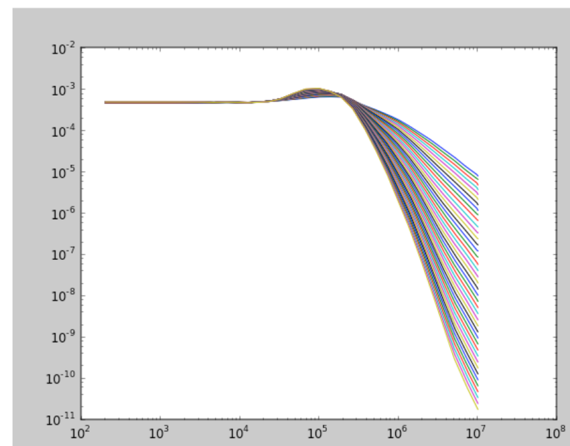
XSPEC/*fits



NAI.fits



BRD.fits



piontemplate.fits

XSPEC command (load the data)

```
[fermiuser@localhost lleBackground]$
[fermiuser@localhost lleBackground]$
[fermiuser@localhost lleBackground]$
[fermiuser@localhost lleBackground]$
[fermiuser@localhost lleBackground]$ xspec

                XSPEC version: 12.7.1
        Build Date/Time: Mon Jul  9 13:47:24 2012

XSPEC12>@loadData int01.xcm
```

```
data 1:1 /home/fermiuser/tools/SolarTutorial/lleBackground/b0_srcspectra.out{1}
back 1 /home/fermiuser/tools/SolarTutorial/lleBackground/b0_bkgspectra.out{1}
resp 1 /home/fermiuser/ospex/glg_cspec_b0_bn100612_0054_038_v00.rsp2
data 2:2 /home/fermiuser/tools/SolarTutorial/lleBackground/LAT_srcspectra.out{1}
back 2 /home/fermiuser/tools/SolarTutorial/lleBackground/LAT_bkgspectra.out{1}
resp 2 /home/fermiuser/FermiData/bn100612038/gll_cspec_bn100612038_v04.rsp
[fermiuser@localhost lleBackground]$
```

XSPEC command (define the model)

```
XSPEC12>@../src/xspec_cmd.tcl
```

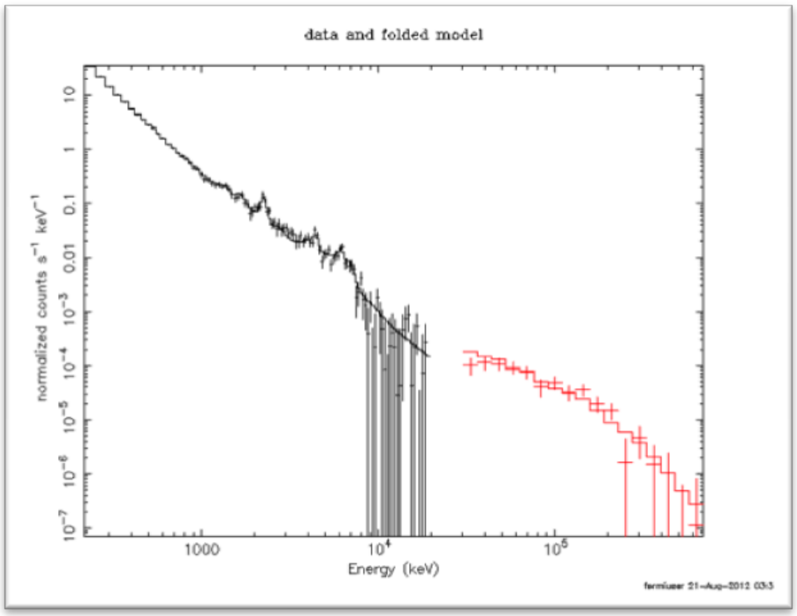
```
setplot energy
ignore 1:1 2e4-**
ignore 2:**-3e4 7e5-**
mod pow+pegpwrl*highecut+atable{../XSPEC/NAR.fits}+atable{../XSPEC/BRD.fits}+gauss+gauss+atable{../XSPEC/piontemplate.fits} & /* \n
newpar 1 2.7
newpar 2 1.0
newpar 3 2.0
newpar 4 1000
newpar 5 1000
newpar 6 1.0
newpar 7 0 -1 0 0 1 1
newpar 8 3e3 100 1e3 1e3 1e6 1e6
newpar 9 4.0
newpar 10 1
newpar 11 =9
newpar 12 = 10*0.75
newpar 13 2.2e3,1e2,2e3,2e3,3e3,3e3
newpar 15 0.1,0.001,0.01,0.01,1000,1000
newpar 16 1.0
newpar 17 511.,1.,500.,500.,515.,515.
newpar 18 0.1,0.001,0.01,0.01,1000,1000
newpar 19 4.0
newpar 20 1.0
statistic chi
fit 100
cpd /xw
plot ld
statistic pgstat
fit 100
show
```

Data group: 1

1	1	powerlaw	PhoIndex		2.52749	+/- 0.131437
2	1	powerlaw	norm		7.04754E+04	+/- 1.18081E+05
3	2	pegpwrlw	PhoIndex		3.81652	+/- 0.143262
4	2	pegpwrlw	eMin	keV	1000.00	frozen
5	2	pegpwrlw	eMax	keV	1000.00	frozen
6	2	pegpwrlw	norm		383.363	+/- 157.164
7	3	highecut	cutoffE	keV	0.0	frozen
8	3	highecut	foldE	keV	1.00000E+06	+/- 5.70023E+09
9	4	NAR	S		4.20000	+/- 8.49254E-02
10	4	NAR	norm		0.501028	+/- 7.04938E-03
11	5	BRD	S		4.20000	= 9
12	5	BRD	norm		0.375771	= 10*0.75
13	6	gaussian	LineE	keV	2225.01	+/- 1.22492
14	6	gaussian	Sigma	keV	11.0515	+/- 0.348688
15	6	gaussian	norm		0.158151	+/- 1.99706E-03
16	7	gaussian	LineE	keV	6.09189E-04	+/- -1.00000
17	7	gaussian	Sigma	keV	500.000	+/- 9825.37
18	7	gaussian	norm		1.00000E-02	+/- 1.05740
19	8	piontemplateS			5.06689	+/- 0.531284
20	8	piontemplatenorm			5.78116E-03	+/- 3.92833E-04

The result

- Using chi^2 statistic is not correct for LLE data, but it is faster and helps to find the minimum.
- The fit MUST be re-run with pg-stat, which assumes Poissonian statistics for the signal, and Gaussian for the background. It's based on likelihood.



This is just an example, you will need to play with the parameter to get the right spectrum… have fun!